Renewable and Sustainable Energy Reviews 25 (2013) 78–88

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Going green: Initiatives and technologies in Shanghai World Expo

Xiaoling Zhang*

Department of Public and Social Administration, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China

ARTICLE INFO

Article history:
Received 17 June 2012
Received in revised form
9 April 2013
Accepted 20 April 2013
Available online 18 May 2013

Keywords:
Green city
Shanghai World Expo
Green technologies

ABSTRACT

The sustainable development steers the green city campaign in the global stage, which has become an increasing challenge particularly to most developing countries in the next decades. This paper aims to investigate green-technologies applicable in the process of developing 2010 Shanghai Expo and the implementation of these green technologies in helping Shanghai city achieve building efficiency and sustainability. A list of green technologies applied in the World Expo has been investigated and key effective green technologies have been identified by using a questionnaire survey. This is followed by case studies to investigate the extent to which these green technologies have been applied to achieve the sustainable development of cities. The findings suggest that a paradigm shift in urban planning and building design is needed and proactive financial measures to encourage the application of green technologies should be formulated. The suggestions can help guide the future direction on the practical approaches towards green cities.

Contents

1. Introduction

Today, half of the world's population lives in towns and cities [1]. The level of urbanization, the number and size of the megalopolis in the world are unprecedented. During the past two decades, the rate of urbanization has become so great that large and medium-sized cities as well as extensive slum-like development has occurred [2]. This is particularly true in China. Nearly all of China's population growth in the past 20 years has occurred in cities. Over the past 50 years, the country's urban population has increased more than seven-fold, from 72 million in 1952 to 540 million in 2004.

Nevertheless, as cities grow, managing them becomes increasingly complex. If well managed, cities offer important opportunities for economic and social development. Cities have always been focal points for economic growth, innovation, and employment. Of particular concern in the process of fast urbanization are the risks to the immediate and surrounding environment, to natural resources, to health conditions, to social cohesion, and to individual rights [3].However, over the past decades, cities have been seen as the sources of environmental degradation and resource depletion [4–6]. These environmental effects have brought great challenges to cities in the 21st Century. The main challenge, therefore, is not competition among the cities, but the challenge of being sustainable urban development. Few of the

* Tel.: +85 234 422 402; fax: +85 234 420 413.
E-mail address: xiaoling.zhang@cityu.edu.hk

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.04.011

megalopolis has yet met all those challenges of 21st century – low carbon energy, public health for an aging population, clean water, reduced air and water pollution, effective waste management and resilience to global climate change. This is echoed with the principles of sustainable development practices addressed by the Bruntland Commission Report [7]. The promotion of sustainable development mission has been shaping the practice of all sectors including city development towards sustainable practice, which works for the balance between economic, social and environmental performance. All large cities need to invent new approaches to practice the principles of sustainable development. The promotion of sustainable practice in urban development has resulted in the development of various green technologies especially for improving environmental performance. Sustainable urban development has therefore constituted a crucial element affecting the long-term outlook of humanity [8].

Initiatives favoring sustainable urban development are varied in nature, spanning from information campaigns, solutions for maintaining the quality of built environments, zoning approaches for preserving valuable natural areas and working landscapes to financial incentives and to policies and regulations [9]. The OECD has analyzed regional specialization and cluster strategies as the intersection of three policy families: regional policy, science and technology or innovation policy, and industrial/enterprise policy [10]. One exemplar is the Chicago Metropolis 2020 plan in which public interest goals of sustainable development are met while realizing narrower aims) [11]. The Chicago case has demonstrated the strategies from stakeholders that can be used to safeguard the environment, encourage neighborhoods with mixes of building types and housing affordable to a range of incomes, and require inner cities and older suburbs that are compact and walkable [12]. Among the initiatives for achieving the sustainable urban development, green technology is considered as one of the important and effective approaches. And the mega-event is regarded as valuable opportunity to promote the goal of green city. The theme “Better City, Better Life” of the 2010 Shanghai World Expo intends to signal a sustainable urban development future for China. Shanghai World Expo is held over a six month period, from May to October 2010. Shanghai authorities are determined to take this opportunity to promote a greening Shanghai by engaging various green technologies. Shanghai's commitment to a Green Expo has resulted in significant effects. Many pavilions on display have adopted the environmentally conscious design elements, like energy-efficient heating and cooling systems, recycled building materials, and green wall.

It is necessary to investigate whether or not the green technologies adopted by cities are implemented or to what extent they may help mitigate environmental challenges imposed in the process of urbanization. It appears nevertheless that little study has been conducted on the extent of implementation of applying various green technologies in helping city achieve sustainability. The lack of understanding is considered as one of the critical issues affecting the promotion of sustainable development in urban cities. The paper therefore aims to investigate green technologies applicable in the process of developing Shanghai 2010 World Expo and the implementation of those green elements in helping Shanghai city gain building efficiency and sustainability. It analyzes to what extent Shanghai Expo has caught the essence of sustainable development, and goes on to identify lessons one can learn for the improvement of sustainable urban development. Special attention is given to the examination of the green technologies in two demonstration projects in the Expo. The results can lead to better understanding on the green essence of developing a sustainable city and approaches to achieve it.

The rest of the paper is organized as follows. The following section reviews green initiatives commonly used in urban development in line with the principle of sustainable development. This is followed by an analysis of the case of Shanghai on the green effects of the Expo. The analysis will be conducted by using the data from a survey and by investigating the extent of effect brought by the green technologies in the two cases. The final section extracts lessons from our empirical investigation and summarizes major concluding remarks.

1.1. Green city practice: initiatives and technologies

Despite various constraints, there has been much headway for propagating innovative, low-cost, and sustainable technologies to mitigate pressing urban problems. This has been made possible by many individuals, communities and organizations. In the previous practices, many researchers, stakeholders, communities, and organizations have been introducing various green technologies for achieving green city. For example, urban planners have adopted various design principles and techniques when designing cities and infrastructures [13]. Developers and contractors adopt various means to reduce collective environmental impacts during the production of building components, construction process, as well as the lifecycle of the building. For example, emphasizes are given to the efficiency of heating and cooling systems [14], green roof technology [15,16], solar systems [17], prefabricated concrete technology [18] and Low-E insulation window technology [19]. These green guidelines for high performance buildings include Energy Star, the National Association of Home Builders' Green Home Building Guidelines, and Leadership in Energy and Environmental Design (LEED) [20]. The main green technologies that cities employ today were identified through a literature review and can be generally categorized in five broad areas: urban planning, buildings, transportation, urban waste management and urban water management.

1. Technologies for sustainable urban planning:
   - Urban climate modeling technology [21]
   - Spatial information technology (GIS, GPS and GNSS) [22]
   - New observation method and technology (remote sensing, ground observation network) [23]
   - Atmospheric environment assessment [24]
   - Landscape simulation technology [25]
   - Air ventilation assessment [26]
2. Technologies for green buildings:
   - Incorporate energy-efficient design into the site layout and building design to reduce nonrenewable energy use [27]
   - Prefabricated concrete technology [28]
   - Ground source heat pump technology [29]
   - Use local, reclaimed, renewable and recycled materials if possible [30]
   - Cooperative energy efficiency design for sustainability [31]
   - Green roof technology, e.g. sedum transformation of eco-roof [32]
   - Energy-saving windows programs [31]
   - Reduce the urban heat island impact resulting from new buildings and paved surfaces [33]
   - Solar PV panels [34]
3. Technologies and strategies for green transportation:
   - Transit oriented development (TOD) [35]
   - Alternative transportation tool to improve opportunities to utilize public transit [21]

Alternative transport fuels (biofuel/electric) [31]
Invest in transport systems and infrastructure that reduce dependence on fossil fuel use [30]
Neutralize carbon emissions from unavoidable travel [30]

4. Technologies for urban waste management:
   - Encourage reuse, recycling and composting technologies thus generating energy [30]
   - Waste classification and recycling technologies [36]
   - Expert systems to waste management planning [37]
   - Waste Incineration Directive (WID) emissions technology [38]

   Converting technology on municipal and industrial wastes [39]
5. Technologies for urban water management
   - Water reuse and reclamation treatment tools [40]
   - Black- and greywater cycle systems [41]
   - Green infrastructure materials for urban water system [42]
   - Biogas micro digester for waste water treatment technology [43]
   - Physical and institutional integration by design in between water supply, wastewater, and Stormwater [44,45]
   - Decentralized water treatment system for collection and treatment plants [46]

Various technologies and strategies have been implemented in many cities, but the effects that these have and the comparison with other technologies implemented elsewhere remains an open question. If cities are to become sustainable, they must reduce their use of all resources and decrease their waste outputs. On the other hand, the liveability of the community and neighborhood should be guaranteed. For example, green buildings can maximize the use of solar PV panels, Low-E windows as well as green roof technologies, thus reducing heating and cooling needs. In this way, renewable energy can be supplied by solar hot water technologies. Water reuse and reclamation treatment technologies could be employed to save limited water resources and rain water collection technologies can be harvested and stored at a local level. As for the transportation aspect, it is nearly impossible to replace all the oil with other renewable energy or resources. Electrically powered vehicles using renewable energy sources would be considered as one of the options [21,47].

Generally speaking, the overall aim of green technologies is to maximize the possibility that cities can meet their needs from the natural capital of their own bio-regions in a renewable way. The categorized themes described above is to be achieved by calling for all stakeholders' participation, the deployment of localized or regional-scale employment of green technologies, the increasingly behavior changes from all sectors, from urban planning concept, building way, water efficiency, energy and resources saving, waste management regulations and a strong support from local and central government.

A number of cities and towns across the world have developed green principles tailored to their own needs [20]. In Japan, over the last few years, Tokyo has unveiled a slew of environmentally conscious initiatives, including toughened environmental building standards, cash incentives for residents to install solar panels and a trees planting plan for greening the city [48]. In India, three major initiatives in achieving green city are introduced, including the techniques of low-cost sanitation, low-cost housing, and rainwater harvesting [49]. In the City of Fresno of USA, up-to 25 green initiatives are implemented in the process of improving urban sustainability. They are, for example, to increase the use of renewable energy to meet 50% of the city's annual electrical consumption of kW h; to develop a system for accounting and auditing greenhouse gas emissions; and to increase by 10% the use of recycled water and the implementation of a sustainable urban watershed planning process. All of these green initiatives have brought about positive effects to improve city's sustainability performance [50]. In China, the Chinese government has launched the construction of an "eco-city" of Dongshan in Shanghai. It was reported that the Dongtan project would become "the world's first genuinely eco-friendly city," by using many green technologies, such as the recycled water, cogeneration and biomass for energy, and striving to be as carbon-neutral as possible [51]. The government plans to use Dongtan as an example to promote sustainable urban development in China. There are also many other cities in the world earnestly provide greenery in new development and preserve existing greenery in redevelopment and expansions [52,53]. Many other researchers have been conducting research on green practice in referring to the sustainable city development. Camagni et al. [9] proposed that a reduction in the use of polluting technologies is one way of keeping environmental constraints under control, through less polluting transport means, less polluting heating systems, and in general through more energy efficient approaches. Green spaces

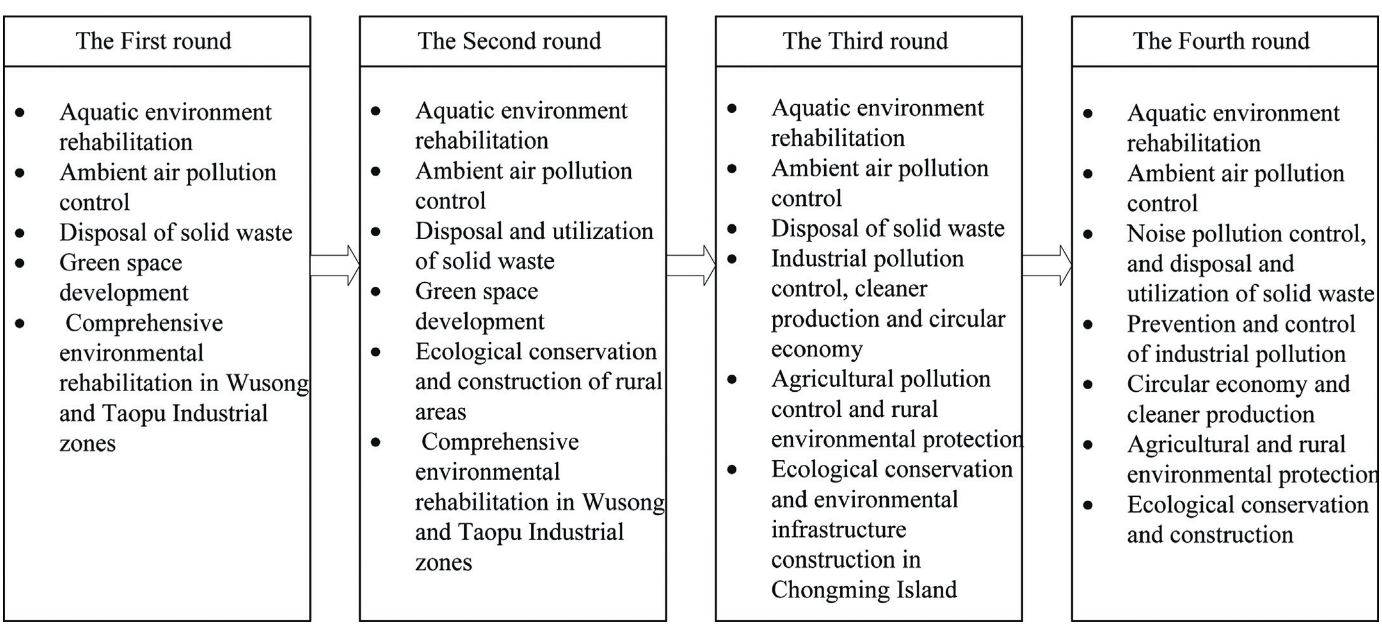

Fig. 1. Progression of priorities from the first round to the fourth round of Three-Year Environmental Action Plan (Source: Environmental Report Expo 2010 Shanghai China, 2009) [31].

designated for preservation in construction sites are proposed for special attention because the protected vegetation commonly lacks proper care [54,55]. Landscape ecology technologies related to the size, shape and connectivity of land are promoted for application in the green-space planning [56,57]. The above discussions leads to the analysis on the green technologies employed in the 2010 Shanghai World Expo and the effects of the green actions.

1.2. Overview of green strategy in 2010 Shanghai World Expo

"Better City, Better Life" is used as the theme of Shanghai World Expo in 2010. The theme aims to promote solutions to mitigate the problems that cities meet and to strike a balance between urban social-economic development and environmental protection. Shanghai has been exploring an appropriate mode of sustainable development with accelerated efforts in building a resource-effective and environmental friendly city. Since 2000, Shanghai municipal government has scaled up and accelerated its environmental initiatives. By taking the opportunity of hosting Expo 2010, Shanghai city has made headway in going through four rounds of Environmental Action Plan (Fig. 1), in order to achieve a resource and energy efficient and environmental friendly city. As can be seen from Fig. 1, extensive efforts have been initiated to promote comprehensive environmental rehabilitation, strengthen pollution control measures, and utilize cleaner and energy-efficient technologies as well as ecological conservation and construction of rural areas.

The Three-year Environmental Action Plan (EAP) has greatly advanced the green process of the city by engaging key environmental projects, such as energy-conservation and emission reduction. This has provided a solid foundation for developing a green World Expo. As shown in Fig. 1, the Shanghai government has paid a huge amount of efforts in the four-round EAP initiatives, which can be described as follows:

- The Three-year Environmental Action Plan (EAP) mainly focused on the energy, industry, transport and construction sectors. Four rounds of proactive measures are conducted to improve the urban environment of Shanghai, which enable it to be ready for Shanghai World Expo. One of the focal issues on energy saving. For example, Shanghai has raised the approval requirements for "energy-intensive with low-added value" industries (such as steel, concrete, coking, petro-chemical, aluminum, and copper refinery industries), and accelerated the phasing out of heavily polluting industries [58].
- Throughout the four rounds of the EAP, industry adjustment and regulation is of utmost significance in Shanghai. For example, they aim to adjust industry structure and pattern which aims to promote the conversion of economic development approach. One of the pilot task forces is the "comprehensive environmental rehabilitation in Wusong and Taopu industrial zones". For example, at Wusong Industrial Zone, 17 heavily polluting enterprises and 40 production lines had been closed down, adjusted or relocated.
- During the four rounds of EAP, the environmental infrastructure construction was gradually accelerated to achieve the economic and effective treatment on air pollution. In line with the national "11th Five-Year" plan, the system "If projects are to be approved, the total polluted emission should be assessed first", the pollution reduction measures have been vigorously promoted, so that the total discharge of major pollutants have been effectively decreased. The concept of "prioritizing public transportation" was introduced in government documents in the 1990s. But it was only in the last few years that clear political determination and substantial policy support were guaranteed.
- Circular economy and cleaner production are heavily promoted in the four rounds of EAP. For example, in Shanghai's industrial zone circular economy pilot projects (Chongming island), measures such as clean energy alternatives, coal-fired stove, separate collection of solid waste, comprehensive utilization of waste, recycling of waste materials, cleaner production of industrial enterprises have been implemented.

According to the existing study and reports, there are three primary green objectives in hosting the World Expo, including (1) minimizing negative environmental impacts; (2) showcase green solutions; and (3) making the city greener.

Green construction site planning has been greatly emphasized. According to the Environmental Impact Assessment of the Master Plan of 2010 Shanghai Expo, 21 major industrial pollution sources were identified in the site area in 2000. Proactive technologies for dealing with these pollution areas are conducted in order to facilitate the green goal of Shanghai World Expo, for example, the shutdown of Nanshi Power Plant, the removal of Shanghai Pudong Iron & Steel Group and Jiangnan Shipyard. And seven historical buildings were classified and preserved as "Outstanding Early Modern Architecture", which would be restored for exhibitions, cultural exchange and recreational functions.

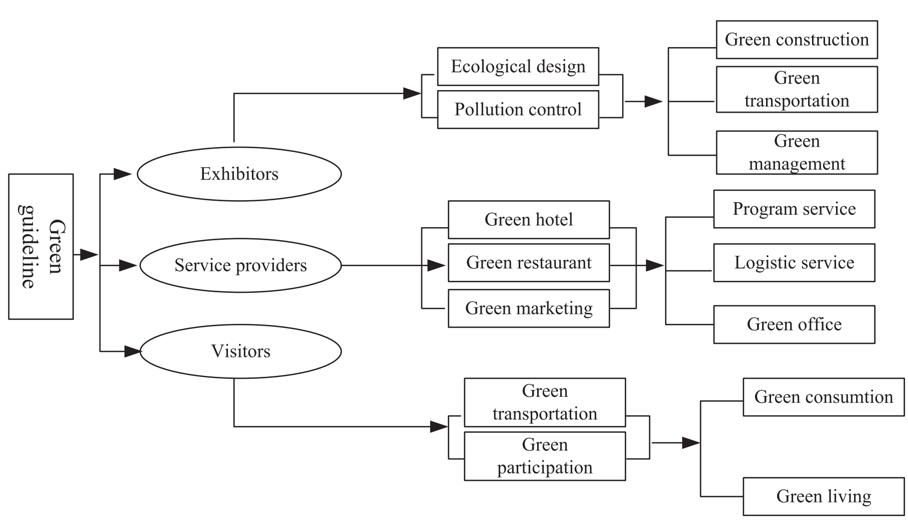

Fig. 2. The Framework of Expo 2010 Shanghai China Green Guide.
(Source: Bureau of Shanghai World Expo Coordination, 2010) [59].

Table 1
Summary of green technologies (GT) used in the Shanghai World Expo.

Technology	Category	Scope of application	Environmental benefit	Pavilions
GT_1 – rainwater control and utilization	Water saving and utilization	Integrated with roof design	–Reduce storm water runoff and resulting pollution	China National Pavilion
GT_2 – building-integrated rainwater collection and reuse systems		All the major permanent new buildings in the site	–Water collected would be reused for greening irrigation and road cleaning	The Expo Center; the Performance Center; the Theme Pavilions; the China National Pavilion and the Expo Axis
GT_3 – roof garden and green wall		Roofs and external walls	Mitigate the urban heat island and enhance the building thermal and environmental performance	Theme Pavilion; Special Steel Stage for the World Expo; Swiss Pavilion
GT_4 – solar photovoltaic power generation	Renewable energy	Installed capacity of 0.4 MW	– Annual saving of 107 TCE – Annual CO_2 reduction of 285 tons	China National Pavilion; the Expo Center; the Nanshi power plant; the Theme Pavilion
GT_5 – locally designed "Shanghai Ecological Home"	Architecture design	External design	The green architecture and outlines the green buildings in the city for 2030	The Urban Best Practices Area
GT_6 – curtain walls with double-glazed windows		Facade of the provincial pavilion (the extension structure)	Energy saving by more than 25% compared with conventional designs	China National Pavilion
GT_7 – Thermal storage air conditioning	Air conditioning	14 units of thermal storage units for ice	– Utilizing off-peak energy – Energy saving	China National Pavilion; the Expo Center; the Performance Center
GT_8 – ground-thermal heat pumps		In the construction site	–Provide cooling in summer and warming in winter for the buildings	The Expo Axis and its Underground Complex; the Performance Center; the Expo Center and the Best Urban Practice Area
GT_9 – energy saving elevators	Building facilities	All elevators	Energy saving	China National Pavilion
GT_{10} – permeable pavement	Building material	The Plaza	Reducing storm water runoff	China National Pavilion
GT_{11} – recyclable building materials over cement and bricks		Temporary structures	They can be disassembled, collected, and reused	Temporary pavilions for exhibitions
GT_{12} – water saving toilets	Greening	All toilets	Water saving	China National Pavilion, the Performance Center
GT_{13} – light-emitting diode (LED)		In the Expo site	Green lighting and indoor and outdoor illumination	The Urban Best Practice Area

Note: the data in this table was summarized by the author according to the UNEP environmental assessment report, 2010 [31].

The effective environment management system was established in developing the Expo project. The roles and responsibilities of various departments in the entire life-cycle of the Expo were clearly defined in the established environment management system. The green city goals are clearly specified by performing the tasks regarding environmental protection on the stages of bidding preparation, planning and design, construction, operation and subsequent utilization. One of the typical examples of well-defined measures in the environment management system is the framework of Participation Guidelines for 2010 Shanghai Expo, which is published by the Organizer (Fig. 2). It can be identified that exhibitors, service providers and visitors are encouraged to take due actions for improving their environmental measures and practices.

The development, application and demonstration of advanced environmental friendly and energy-efficiency technologies are the focus of achieving the green mission in Shanghai World Expo. The large-scale demonstration of using renewable energy and energy saving technologies in the venues and pavilions demonstrates the ways of helping cities re-orient their energy technologies toward a low-carbon future. Major green technologies adopted and demonstrated in 2010 Shanghai World Expo are summarized in Table 1.

It is considered that the green technologies have been actively promoted in the Expo site during the whole process of the event, including planning, construction, operation as well as reusing after the Expo. There is an extensive application of environmental and energy-conservation technologies in the mega project, such as solar photovoltaic, river water/geo-thermal heat pump, ice thermal storage, rainwater reuse, renewable energy vehicles and low-carbon technologies. The 2010 Shanghai Expo has set a good example of friendliness to the environment and taken the lead in shaping a sustainable mode for future urban development [60]. At the same time, Shanghai city has been greened with parks and greenways in line with the implementation of the project. Much effort has been made to promote green buildings in the newly renovated commercial areas in Shanghai, and these buildings are expected to have new life in the changed city fabric.

2. Research methods

The data and information used for analysis in this study are collected in Shanghai, which was conducted between October 2009 and February 2010. The investigation focuses on the green measures developed for Shanghai World Expo 2010. A questionnaire survey was conducted in order to understand the significance of applying various green technologies to build an energy efficient as well as sustainable city. Though it is accepted that sustainability includes "triple bottom lines" that are interconnected with social, environmental and economic issues, this study focuses on examining the environmental impacts and consequences of green initiatives.

The questionnaire survey in this study was conducted among professionals participating in the development of Shanghai World Expo. The initial list of 498 professionals is identified with the help of Bureau of Shanghai World Expo Coordination, Tongji University and Zhejiang University including government officials, architects, academics, civil engineers, contractors, environmental volunteers, and NGOs. Then, invitation letters were sent to these identified professionals to participate in the survey. One hundred and fifty-five professionals replied and indicated their willingness to participate, and therefore the full-set questionnaire was distributed by e-mail or post to those accepting the survey invitation. To increase the sample size, a 'snowball' sampling method was used. The respondents were invited to help distribute the questionnaire to their colleagues and their business partners or senior practitioners

whom they knew to have a rich experience in the area. As a result, 408 questionnaires were dispatched via both e-mail and conventional post. Due to the limitation of time, the respondents were given only one month to complete and return the questionnaires. Finally, the response rate of the survey was 42.9%. One hundred and seventy-five effectively completed questionnaires were returned and used for analysis (Table 2).

The questionnaire was designed to focus on professional opinion on the contribution of green technologies to building energy efficient as well as sustainable city. A Likert scale was used to help respondents present their opinions, which is commonly used for rating the relative significance of individual factors through expert opinions [61,62]. In order to determine the respondents' knowledge of green building experience level, the respondents were asked; "How many green projects have you been involved with?" (more than 5 projects = 5; 2–5 projects = 4; less than 2 projects = 3; no projects completed but green projects planned this year = 2; no projects underway or planned but knowledgeable on green buildings = 1). The participants were also requested to assign an appropriate rating on the basis of 1–5, from the lowest to highest level. In order to further explore the dimensions of the respondent's perceptions about the contribution of each green element to achieving energy efficiency and sustainability of a city, the question "How much significant contribution is the green technology to the overall sustainability of a city" (very much significant = 5; somewhat significant = 4; neither significant nor insignificant = 3; somewhat not significant = 2; not significant at all = 1) was asked.

Table 2
Classification of the survey respondents.

Classification of the respondents	No.
Government officials	27
Architects	16
Academics	35
Civil engineers	31
Environmental volunteers	40
Contractors	19
NGOs	7
Total	175

Table 3
The response result: mean value of green technologies.

Factors	*Number of respondents' scoring*					Mean score (MS)	Rank
	1	2	3	4	5		
GT_4	0	0	2	21	22	4.44	1
GT_3	0	0	8	24	13	4.11	2
GT_{13}	0	0	10	28	7	3.93	3
GT_{11}	0	2	20	21	2	3.51	4
GT_2	0	3	26	16	0	3.29	5
GT_6	1	7	23	14	0	3.11	6
GT_1	0	11	26	8	0	2.93	7
GT_8	2	13	23	7	0	2.78	8
GT_5	0	19	21	5	0	2.69	9
GT_7	1	16	25	3	0	2.67	10
GT_9	1	17	25	2	0	2.62	11
GT_{12}	2	19	20	4	0	2.58	12
GT_{10}	4	19	21	1	0	2.42	13

Data from the media reports, academic papers and internet searching were used to compare with the results from the questionnaire survey for further analysis. In addition, three field visits were made to the Expo Site and pavilions when they were under construction to further verify the analysis results from the questionnaire survey.

2.1. Evaluation on the effects of the green technologies

The analysis of the questionnaire survey usually adopts the descriptive techniques [63]. The five-point Likert scale described previously was used to calculate the mean score for each benefit, which was then used to determine the relative ranking of different significances by comparing the individual mean score for each green technology in descending order of importance. The mean score (MS) for each factor was calculated by the following formula [64–66]:

$$MS = \frac{\Sigma(P \times R)}{N} \quad (1 \le MS \le 5) \tag{1}$$

where P = score given to each green technology by the respondents and ranges from 1 to 5, where 1 is "not significant at all" and 5 is "very much significant"; R = frequency of response to each rating (1–5), for each green technology; N = total number of response concerning that green technology.

The ranking of the 13 green technologies was derived on the basis of the mean values of responses, as summarized in Table 3 and Fig. 3. It can be seen that the most effective green technologies for achieving the energy efficiency in city is "solar photovoltaic power generation", with the highest mean value rating of 4.44. This is followed by "roof garden and green wall" (4.11) and "light-emitting diode (LED)" (3.93). The "recyclable building materials

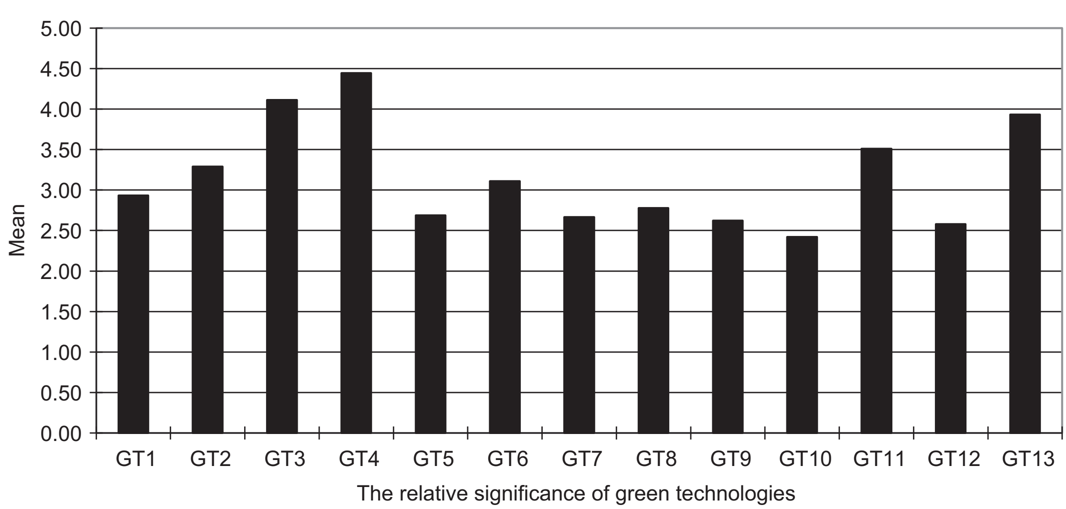

Fig. 3. The relative significance of green technologies for achieving sustainable cities.

over cement and bricks" and "building-integrated rainwater collection and reuse systems" were ranked as fourth and fifth respectively.

3. Case study: green effect of Shanghai World Expo

In this section, the analysis is given to the implementation of green technologies in the 2010 Shanghai World Expo. The data used for this analysis are collected from two case studies by conducting interviews with the engineers and project managers in the Expo Site and pavilions under construction. The interview discussions are oriented towards the practical use of the top three green technologies, "solar photovoltaic power generation", "roof garden and green wall" and "light-emitting diode (LED)".

3.1. Case 1: theme pavilion of the Expo

Covering an area of 11.5 ha, the theme pavilion building was located near the Expo Axis, in Zone B. The construction area of the building is 152,000 m^2, consisting of 98,000 m^2 above ground with two stories and 54,000 m^2 underground on one level. The construction was completed in September of 2009 before interior construction began. According to the general project manager who is in charge of the theme pavilion, he introduced that the pavilion is featured with "solar photovoltaic systems on the rooftop" and "green walls". The Solar PV system is considered as the world's biggest "non-column space". Both the eastern and western exterior walls of the pavilion are installed with green walls, which are considered as the largest ecological walls in the world.

The roof's solar PV system was put into use at the end of September, 2009 (see Fig. 4). A total of 2.83 MW of solar photovoltaic panels were installed on the theme pavilion. Solar-powered street lamps, lawn lamps, and other lighting as well as solar thermal heating systems are also widely used in the Expo site. Through grid-connected power generation, the electricity generated by solar power is transmitted to the urban power grid. The solar PV system can generate 2.8 million kW h per year – which provides sufficient electricity for 2500 Shanghai families for a year. According to the interview discussion with the professionals on the site, the electricity generated can reduce carbon dioxide discharges by 2800 t each year. The generated energy can save as much as 893 t of coal reduction each year. However, as one of the emerging advanced technology, the installation of the photovoltaic curtain walls posed greater challenges than that of the traditional curtain wall. The huge amount of architectural design has also brought a lot of difficulty to the construction. This is echoed by the interviewee

> "…The total area of the West Hall of the Theme Pavilion exhibition is 25,000 m^2. While it is considered as the world's largest two-way span column-free exhibition hall, which therefore made the stability of the solar panels installed as one of the key challenges to the construction…(Interview, 25th October, 2009) "

The vertical ecological green walls on the Theme Pavilion's east and west elevations cover 5000 m^2, making it the world's largest eco-wall. The annual absorption of CO_2 is up to 4 t, dust capacity is 1 t and energy consumption is 40% lower than that of conventional glass curtain walls. "In summer, they can stop the radiation of sunshine, block thermal radiation and cool down the air near the wall to reduce heat transmission. In winter, they can lower wind speed and form an insulating layer, without any influence on the process of absorbing heat from sunlight and at the same time, by decreasing the wind speed nearby, the service life of the exterior wall can be extended", commented by the general project manager. It is also mentioned by him that the wall was built by the scientists from Shanghai Botanical Garden by using advanced technology. The green wall adopted plants as a litter and other organic waste soil and fertilizer, and applied the paper processing plants into cultivation Environmental protection Type pot (see Fig. 5). Gardeners chose hardy plants that can endure a hot and wet environment and require minimal maintenance. They include photinia, glossy privet, honeysuckle, abelia and China star jasmine. In this sense, the cost is less than one-tenth of the same technology from overseas. On the other hand, it is estimated that the 5000 m^2 of green area can help retain 870 t of dust, sequester 3175 t of carbon, reduce 96 t of carbon dioxide emission and save 125,000 kW h electricity for air conditioning annually. As the core green wall technology is independently studied by Shanghai Botanical Garden, it is considered feasible to apply the research outcome into a larger scope. This is echoed with one of the interviewees,

Fig. 4. The Solar PV on the Theme Pavilion (Source: Footprint, 2010) [67].

Fig. 5. The view of the vertical ecological green wall on the theme pavilion.

> "…The Green wall facilities module could be designed as modular from factory production and the material is recycled plastic with no less than 8 years' life. For ease of construction, the plant must be re-planted after the module is installed with strong loading capacity. Another innovation from the green curtain wall is to use waste paper pulp as the container. The waste paper pulp is breathable, degraded and could be blended with soil and plant roots after three months. Moreover, there is

no need for special water conservation, supported with automatic drip irrigation technology. It is therefore considered good to apply into old houses, streets and high-rise buildings for greening. Currently, there is more than one real estate company that requires cooperation with the Task Force. The greening World Expo is therefore close to public…" (Interview, 26th October, 2009)

Spotlight on the green technologies in this case study (summarized from the interview report by the authors):

- Use of roof garden and green wall (GT_3)
- Use of solar photovoltaic power generation (GT_4)
- Use of building-integrated rainwater collection and reuse systems (GT_2)

3.2. *Case 2: China National Pavilion*

The China National Pavilion is located halfway along the Expo Axis on its eastern side in Zone A of the Expo Park. Covering 160,000 m^2 in floor space, the pavilion is composed of a national hall and a regional hall. China National Pavilion, in a structural design of Dougong brackets, features wooden brackets fixed layer upon layer between the top of a column and a crossbeam (Fig. 6). The building is red in appearance, which bears the elements of traditional Chinese culture. However, it is green indoors, with the use of energy-saving and environment-friendly technologies. As introduced by the chief engineer of the China National Pavilion, "in summer, the upper layer can serve as a natural sunshade, which effectively reduces the air conditioning energy consumption."

The China Pavilion is fully ventilated and has adopted many solar powered technologies, which can guarantee a strong power supply and provide all of the electricity for the lighting needed by this building. A total of 0.302 MW of solar photovoltaic panels are installed on the China National pavilion. It will generate an annual power output of 300,000 kW h, which equals the power generation by burning 107 t of standard coal. In this context, the emission of CO_2 will be reduced by 285 *t*.

Another green technology, the Light-emitting diode (LED), is adopted as the main technology for indoor and outdoor illumination of the building. The light-emitting diode (LED) is a new lighting source in solid state which can convert electric power directly into visible light and radiation power. Compared to conventional incandescent light-bulbs, LED lights are characterized with lower energy consumption, small size, longer lifetime, high reliability, fast response characteristics, energy-conservation and environmental-friendly and intelligent switching. In reality, it can result in a 70% energy saving and are more durable and colorful. This is echoed with one of the interviewee,

Fig. 6. The construction site in the China National Pavilion.

Fig. 7. The light-emitting diode (LED) technology in the China National Pavilion.

"…*As* we know, traditional light is hot which carries with it a waste of energy. LED belongs to cold light which does not heat, which can save 25% energy in this particular function itself. According to the accurate calculation of the Expo Park, 1700 sets of LED lighting system could save as much as 60% than traditional lighting and the energy saving in the main road and stairs by using LED lighting has reached 75%…" (Interview, 27th October, 2009)

According to the chief engineer of the China National Pavilion, "Illuminating the building, which has a vertical height of 66 m, is not an easy task (see Fig. 7). Standard floodlights are not powerful enough to reach the great height while maintaining their vibrancy, but by using state-of-the-art light-emitting diodes (LED) high-powered floodlights, the challenges can be met". The expected longevity of the lights used for the China Pavilion is 15 times that of traditional light bulbs, which will save a great amount of energy.

Spotlight on the green technologies in this case study:

- Use of light-emitting diode (LED) (GT_{13})
- Use of solar photovoltaic power generation (GT_4)
- Use of water saving toilets (GT_{12})

4. Discussion

According to the questionnaire designed for the interview discussion with the key informants, the major implementation level of the Green technologies (GTs) can be obtained. The results are assisted by an exemplification framework, and the implementation level for GTs can be identified (see Table 4). By comparing the two cases, the result can be shown in Table 5.

According to the information in Table 5, the following results can be drawn:

The practices show that significant differences exist in applying GTs in the planning, construction and operation and maintenance stages. Seen from the two case studies, it is obvious that solar PV (GT_4) is considered as the most frequently adopted green technologies in the Expo site. The result is echoed with the questionnaire survey result. Solar photovoltaic power is a typical type of renewable energy, being able to be used in standard industrial lines with minor modifications. It is reported that solar photovoltaic systems today are more than 60% cheaper than they were in the 1990s. In this context, it is more simple and efficient to facilitate the goal of energy saving and urban sustainability. This has been echoed with another two typical urban cases.

Table 4
Framework on the exemplification on the implementation level of GTs.

Stage	Level	Characteristics
Planning stage	◆	Poor control of the adoption of GTs. There is no clear responsibilities and management of the application of GTs
	◆◆	There is a clear holistic plan to use GTs. All participants respect the dates and schedule
	◆◆◆	All of the key participants have joined the designing and planning in the early phases of projects to contribute to the proactive implementation of GTs
	◆◆◆◆	There are clear regulations between sub-processes where certain tasks on GTs must be implemented
	◆◆◆◆◆	There are a systematic planning and controlling procedures to investigate each of the performance and feedback on the progress of implementing GTs from the initial stage
Construction stage	◆	There is no clear regulation when GTs are implemented on site
	◆◆	There are simple regulations of the GTs which are made and posted on site
	◆◆◆	There is a detailed handbook for implementing GTs to all the participants involved in the construction process.
	◆◆◆◆	They have held several training courses on demonstrating the implementation of GTs prior to the launch of the construction project
	◆◆◆◆◆	To make sure that the GTs are appropriately implemented and installed, the whole construction progress on site will be supported by BIM system, which will facilitate the whole process
Operation and maintenance and reuse stage	◆	There is no clear regulation on maintaining the GTs
	◆◆	Simple regulation on maintaining the GTs is designed. Examples are attached on site
	◆◆◆	There is a set of procedures designed for the maintenance of GTs after the completion of projects
	◆◆◆◆	A regular monitoring system is set up to check the performance and maintenance of GTs
	◆◆◆◆◆	There is a regular checking system to monitor the GTs assisted by BIM tools; there are a group of facilities management staff who are responsible to maintain GTs over time

Note: ◆ = 1, lowest implementation level; ◆◆ = 2, relatively low implementation level; ◆◆◆ = 3, middle level of implementation level; ◆◆◆◆ = 4, relatively high implementation level; ◆◆◆◆◆ = 5, highest implementation level.

Table 5
Comparison on the implementation level of GTs in the two cases.

	Planning stage	Construction stage	Operation and maintenance and reuse stage
Case 1:	GT_3: ◆◆◆◆	GT_4: ◆◆◆◆	GT_4: ◆◆◆◆
	GT_4: ◆◆◆	GT_2: ◆◆◆◆	GT_2: ◆◆◆
	GT_2: ◆◆	GT_3: ◆◆◆	GT_3: ◆◆◆
Case 2:	GT_{13}: ◆◆◆	GT_{13}: ◆◆◆◆	GT_4: ◆◆◆◆
	GT_4: ◆◆◆	GT_4: ◆◆◆	GT_{12}: ◆◆◆◆
	GT_{12}: ◆◆	GT_{12}: ◆◆◆	GT_{13}: ◆◆◆

One special case is Singapore. As the urbanization challenge is acute in Singapore, where population density is high. Through the efficient use of energy and the optimization of available natural resources, Singapore has demonstrated how a city may enhance economic productivity and growth, while minimizing ecological impacts and maximizing the efficiency of resource use [68]. Their efforts in exploring the green technologies and endeavors in promulgating government policies of promoting green technologies have demonstrated a good example to achieve a sustainable city. The government of Singapore has supported a lot of R&D research on the application of solar photovoltaic power. For example, the Solar Energy Research Institute of Singapore (SERIS), within the National University of Singapore (NUS), is developing technologies for tropical environments. SERIS is also focusing on building integrated photovoltaic (BIPV) technology to generate solar power from the roofs and façades of buildings. The Singapore expertise in eco-city design is being deployed through an innovative project in China: the Tianjin Eco-city. The Eco-city is being jointly developed by the China Academy of Urban Planning and Design, the Tianjin Institute of Urban Planning and Design, and the Singapore Urban Redevelopment Authority.

Another case is Germany. Freiburg in Germany, a city of 205,000 people that was founded 900 years ago in the wine-growing area of southwest Germany, has been working towards its mission of embracing green technologies since 1986. On the solar front, Freiburg has developed numerous significant projects that use every kind of solar application – solar PV (Photovoltaics – over 400 installations), solar thermal (for hot water), solar sunrooms or “winter gardens”, passive solar design, solar cooling, and transparent solar insulation, which converts the solar heat which hits a wall into useable thermal energy [69]. By December 2003, the total PV capacity in Freiburg had reached 3200 kW (3.2 MW), producing 3 million kW h per year for use in the grid. An additional 8560 m^2 of solar thermal heating had been installed and 700 m^2 of solar swimming pool heating. In 1996, this was strengthened by a city resolution to reduce Freiburg's CO_2 emissions to 25% below the 1992 level by 2010 [70]. By using these green technologies, Freiburg has set up a good example of being a sustainable region as a whole, where the average Freiburg citizen produces 11 t of CO_2 a year, three quarters of which comes from the use of energy in the city.

Compared with Singapore and Freiburg, there is still a long way for Shanghai to go in greening the city. The World Expo 2010 in Shanghai was a great opportunity to demonstrate the city's green technologies to the World. The Shanghai city would garner worldwide focus and global visibility on its efforts and practical experiments on urban sustainability initiatives. The green technologies identified in the survey and case studies in the World Expo are only a small part of the plan for greening the Shanghai city. Most of the Shanghai region still relies on highly polluting coal-fired power plants. It is expected that the practice will change in the coming two or three decades. Shanghai and other Chinese megacities are encouraged to apply more alternative low-emission technologies, including solar and wind power, nuclear power, carbon capture and sequestration, etc. Though the barriers and challenges are acute for Chinese cities toward the green goal, there are two possible approaches:

- A paradigm shift in urban planning and building design:
  Urban planning is critical to the creation of a green city. It can help ensure “sustainable development with no extra cost”. There needs to be a paradigm shift in urban planning, it needs to promote the compact cities patterns, which needs to be balanced with sufficient green urban areas as a prerequisite for a green and livable city. In this context, the good access to green urban areas, their high quality and multiple usabilities are even more important than their absolute share of the municipal's area [71]. This can also be echoed with Singapore's Master Plan in 2008, “a compact city with transit-oriented development at core, strategic decentralization and an integral

leisure plan". In the building design aspect, there are many ways to encompass environmentally conducive measures in the cities. For example, in the southern part of China, where there is plenty of sunlight, solar appliances could be attached to buildings to make use of natural and renewable solar energy. In regions where it rains a lot, rain water harvesting to replenish the water supply should be made mandatory for every new building construction.

- Proactive financial policy or economic measures for the application of green technologies:
  There is a need for financial policies to promote the use of renewable resources, green technologies and the generation of clean water and proper management of waste, so as to improve the living conditions of the city. The tax incentives adopted in Germany is a good example. For example, the feed-in tariff (FiT, feed-in law, advanced renewable tariff (1.3 MB) or renewable energy payments) is a policy mechanism designed to encourage the adoption of renewable energy sources and to help accelerate the move toward grid parity [72]. Similarly, it is considered that the feed-in tariff policy can be adopted in Chinese cities, which can also help stimulate the market growth in green technologies. For example, in applying the solar PV system, the fixed price of the appliance can be determined by public authorities for a certain period. The cost will therefore be paid per kilowatt-hour by electricity companies to producers of green electricity.

5. Concluding remarks

The green campaign in urban cities is a long-term arduous task that aims to develop a stronger synthesis of social, economic, and environmental aspects. By investigating the green technologies together with urban development decision making, this paper explores the green measures applicable in Shanghai World Expo through demonstration projects. The findings from the survey in this study have identified a group of effective green technologies which can help achieve the green city by long-term efforts. The Shanghai World Expo has become a showcase in terms of ecological innovation and is becoming an innovation hub for applying green technologies. In this sense, it is found that the "Solar photovoltaic power generation", "Roof garden and green wall" and "Light-emitting diode (LED)" technologies are most significant in contributing the green city. This finding can guide the future direction on the practical approaches towards the sustainable urban cities. However, a lesson we can also learn from the Shanghai World Expo case is that the green city campaign is a long-term process in which the green goals cannot be effectively achieved through a single event where multiple green technologies are only fractional part of the entire process.

By itself, greening could serve as a necessary but not sufficient condition towards urban sustainability [43], the findings from the study, however, can act as an important part of the urban development paradigm. Shanghai has set up its unique position within China at a time when China will become the world's largest economy. The international mega-event, the 2010 Shanghai World Expo, provides good opportunities to promote the city branding and to enhance the city's green philosophy to large extent. In this context, the Shanghai World Expo has played the living proof that strong central planning can foster the development of green technologies. Nonetheless, these green technologies can only generate influences if long-term efforts are maintained.

References

[1] United Nations (UN) World urbanization prospects: the 2010 revision, United Nations, New York; 2010.

[2] Shen LY, Ochoa JJ, Shah MN, Zhang XL. The application of urban sustainability indicators- A comparison between various practices. Habitat International 2011;35(1):17–29.

[3] Cohen B. Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. Technology in Society 2006;28(1–2):63–80.

[4] Breheny MJ, editor. Sustainable development and urban form. London: Pion; 1992.

[5] Jenks M, Burton E, Williams K, editors. The compact city—a sustainable urban form? E & FN Spon; 1996.

[6] Williams K, Burton E, Jenks M. Achieving the compact city through intensification: an acceptable option? In: Jenks M, et al., editors. The compact city—a sustainable urban form? E & FN Spon; 2000. p. 83–96.

[7] WCED. World Commission on Environment and Development.The Brundtland report, our common future. Oxford: Oxford University Press; 1987.

[8] Auclair C. The UNCHS (Habitat) indicators program.Sustainability indicators—report of the project on indicators of sustainable development. New York: Wiley; 288–92.

[9] Camagni R, Capelloa R, Nijkamp P. Towards sustainable city policy: an economy-environment technology nexus. Ecological Economics 1998;24(1):103–18.

[10] OECD. Globalisation and regional economies: can OECD regions compete in global industries? Paris: OECD Publications; 2007.

[11] Johnson EW. Executive summary: Chicago metropolis 2020. Chicago: The Commercial Club of Chicago; 1999. ⟨http://www.metropolisplan.org/Exec%20Summ.pdf⟩ Retrieved July 9, 2008, from.

[12] Berke PR. The Evolution of green community planning, scholarship, and practice: an introduction to the special issue. Journal of the American Planning Association 2008;74(4):393–407.

[13] Frey H. Designing the city: towards a more sustainable urban form. European Planning Studies 2000;8(5):685–8.

[14] UNEP. Sustainable building and construction: facts and figures. UNEP Industry and Environment; 5–8.

[15] GRHCC About green roofs. Green Roofs for Healthy Cities (GRHCC), Toronto, Ont.; 2003. Available from website ⟨http://www.peck.ca/grhcc/index.html⟩ [accessed 5 December 2003].

[16] Zhang XL, Platten A, Shen LY. Green property development practice in China: costs and barriers. Building and Environment 2011;46(11):2153–60.

[17] Ecotecture Sunlight homes:home page; 2006. Available from website ⟨http://www.sunlighthomes.com⟩ [accessed 4 April, 2007].

[18] Tam VWY. Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. Journal of Cleaner Production 2009;17(7):688–702.

[19] Kirby SD, Williams SE. New look at windows technologies: a look to the future. Oklahoma Cooperative Extension Service; 1991.

[20] Sparks CW. Greening affordable housing: an assessment of housing under the community development block grant and HOME investment partnership programs, Applied research projects; 2007. Available at ⟨http://ecommons.txstate.edu/cgi/viewcontent.cgi?article=1253&context=arp⟩ [accessed June 2007].

[21] Kenworthy JR. The eco-city: ten key transport and planning dimensions for sustainable city development. Environment and Urbanization 2006;18(1):67–85.

[22] Masser I. Managing our urban future: the role of remote sensing and geographic information systems. Habitat International 2001;25(4):503–12.

[23] Yeh AG, Li X. An integrated remote sensing and GIS approach in the monitoring and evaluation of rapid urban growth for sustainable development in the Pearl River Delta, China. International Planning Studies 1997;2(2):193–210.

[24] Alberti M. Urban patterns and environmental performance: what do we know? Journal of Planning Education and Research 1999;19(2):151–63.

[25] Paar P. Landscape visualizations: applications and requirements of 3D visualization; 2006. p. 815–839.

[26] Ng E. Policies and technical guidelines for urban planning of high-density cities – air ventilation assessment (AVA) of Hong Kong. Building and Environment 2009;44(7):1478–88.

[27] Ngowi AB. Creating competitive advantage by using environment-friendly building processes. Building and Environment 2001;36(3):291–8.

[28] Noguchi M. The effect of the quality-oriented production approach on the delivery of prefabricated homes in Japan. Journal of Housing and the Built Environment 2003;18(4):1566–4910.

[29] Doherty PS, Al-Huthaili S, Riffat SB, Abodahab N. Ground source heat pump-description and preliminary results of the eco house system. Applied Thermal Engineering 2004;24(17–18):2627–41.

[30] WWF Report. One_planet_living project; 2006. Available from ⟨http://wwf.panda.org/what_we_do/how_we_work/conservation/one_planet_living/about_opl/principles/⟩.

[31] APEC Energy Working Group. Using smart grids to enhance use of energy-efficiency and renewable-energy technologies; 2011. Available from website ⟨http://www.pnl.gov/main/publications/external/technical_reports/pnnl-20389.pdf⟩.

[32] GRHCC. About green roofs. Green Roofs for Healthy Cities (GRHCC). GRHCC, Toronto, ON; 2003. Available from website ⟨http://www.peck.ca/grhcc/index.html⟩ [accessed 5 December 2003].

[33] Golden JS. The built environment induced urban heat island effect in rapidly urbanizing arid regions–a sustainable urban engineering complexity. Environmental Sciences 2004;1(4):321–49.

[34] Zhang X, Shen L, Chan SY. The diffusion of solar energy use in HK: what are the barriers? Energy Policy 2011;41:241–9.
[35] Litman T, Burwell D. Issues in sustainable transportation. International Journal of Global Environmental 2006;6(4):331–47.
[36] Vanegas, JA, DuBose, JR, Pearce, AR. Sustainable technologies for the building construction industry. In: Proceedings of symposium on design for the global environment, Atlanta, GA; 1995.
[37] Thomas B, Tamblyn D, Baetz BW. Expert systems in municipal solid waste management planning. Journal of Urban Planning and Development 1990;116:150–5.
[38] Omer AM. Energy, environment and sustainable development. Renewable and Sustainable Energy Reviews 2008;12(9):2265–300.
[39] Chang J, Leung DYC, Wu CZ, Yuan ZH. A review on the energy production, consumption, and prospect of renewable energy in China. Renewable and Sustainable 2003;7(5):453–68.
[40] Aspegren H, Hellstrom B-G, Olsson G. The urban water system – a future Swedish perspective. Water Science and Technology 1997;35:33–43.
[41] Otterpohl R, Braun U, Oldenburg M. Innovative technologies for decentralised water-, wastewater and biowaste management in urban and peri-urban areas. Water Science and Technology 2003;48(11–12):23–32.
[42] Grimm NB, Morgan Grove J, Pickett STA, Redman CL. Integrated approaches to long-termstudies of urban ecological systems. BioScience 2000;50(7):571–84.
[43] Zhang X, Platten A, Shen L. Green property development practice in China: costs and barriers. Building and Environment 2011;46(11):2153–60.
[44] Butler D, Maksimovic C. Urban water management-challenges for the third millennium. Progress in Environmental Science 1999;1:213–35.
[45] Lawrence, AI, Bills JB, Marsalek J, Urbonas B, Phillips BC. Total urban water cycle based management. In: Proceedings of the 8th international conference urban storm drainage, 30 August–3 September 1999. Sydney, Australia; 1999.
[46] Heaney JP, Wright L, Sample D. Sustainable urban water management. In: Field R, Heaney JP, Pitt R, editors. Innovative urban wet-weather flow management systems. USA: Technomic Publishing Company; 2000. p. 75–120.
[47] Dincer I. Renewable energy and sustainable development: a crucial review. Renewable and Sustainable Energy Reviews 2003;4(2):157–75.
[48] Dickerson M. Tokyo's goal: be the most eco-friendly mega city. Los Angeles Times (MCT) April 27, 2010 [Available at website 〈http://wildcat.arizona.edu/news/news-from-the-wire/tokyo-s-goal-be-the-most-eco-friendly-mega-city-1.1432092〉].
[49] Chakrabarti PGD. Urban crisis in India: new initiatives for sustainable cities. Development in Practice 2001;11(2 & 3):260–72.
[50] Fresno's Green Report. The city of Fresno's strategy for achieving Sustainability; 2007. Available at website 〈http://www.fresno.gov/NR/rdonlyres/4316C47B-49C5-417A-899C-2A6C7EB4DAD3/0/GreenStrategy.pdf〉.
[51] Cascio J. Green City China, Inhabitat; 2005. Available at website 〈http://www.worldchanging.com/archives/003475.html〉.
[52] Gordon D, editor. Green cities: ecologically sound approaches to urban space. Montreal: Black Rose; 1990.
[53] Beatley T. Green urbanism: learning from European cities. Washington, DC: Island Press; 2000.
[54] Matheny N, Clark JR. Trees and development: a technical guide to preservation of trees during land development. Champaign, IL: International Society of Arboriculture; 1998.
[55] Watson G W, Neely D, editors. Trees and building sites. Champaign, IL: International Society of Arboriculture; 1995.
[56] Cook E. Landscape structure indices for assessing urban ecological networks. Landscape and Urban Planning 2002;58:269–80.
[57] Leitao AB, Ahern J. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning 2002;59:65–93.
[58] The United Nations Environment Programme (UNEP). UNEP environmental assessment Expo 2010; 2010. Available at website 〈http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=594&ArticleID=6271&l=en〉.
[59] Bureau of Shanghai World Expo Coordination. World Exposition Shanghai China Participation Guide; 2010. Available at website 〈http://en.expo2010.cn/expo/expo_english/documents/dc/userobject1ai48802/00000000.pdf〉.
[60] Bureau of Shanghai World Expo Coordination and Shanghai Environmental Protection Bureau. Environmental Report Expo 2010 Shanghai China; 2009. Available at website 〈http://www.sepb.gov.cn/english/downloads/Expo2010.pdf〉.
[61] Sutton SG, Tobin RC. Constraints on community engagement with great barrier reef climate change reduction and mitigation. Global Environmental Change 2011;21(3):894–905.
[62] Shen QP, Liu GW. Critical success factors for value management studies in construction. Journal of Construction Engineering Management 2003;129(5):485–91.
[63] Hill T, Lewicki P. Statistics methods and applications. UK: StatSoft, Tulsa; 2007.
[64] Mbachu J, Nkado R. Conceptual framework for assessment of client needs and satisfaction in the building development process. Construction Management & Economics 2006;24(1):31–44.
[65] Zhang XL, Shen LY, Vivian W.Y. Tam, Lee Winnie WY. Barriers to implement extensive green roof systems: a Hong Kong study. Renewable & Sustainable Energy Reviews 2011;16(1):314–9.
[66] Chan APC, Chan DWM, Ho KSK. An empirical study of the benefits of construction partnering in Hong Kong. Construction Management Economics 2003;21(7):523–33.
[67] Footprint. Shanghai Expo – Amazing photos; 2010. Available at website 〈http://blog.emap.com/footprint/2010/03/17/shanghai-expo-amazing-photos/〉.
[68] Suzuki H, Dastur A, Moffatt S, Yabuki N. Eco^2 cities: ecological cities as economic cities. Washington D.C.: The World Bank; 2010.
[69] Dauncey G. Freiburg solar city; 2003. Available at 〈http://www.solarregion.freiburg.de/solarregion/freiburg_solar_city.php〉 [accessed 21 June 200].
[70] Berrini M., Bono L. Measuring urban sustainability: analysis of the European Green Capital Award 2010 & 2011 application round; 2010. Available at website 〈http://ec.europa.eu/environment/europeangreencapital/docs/cities/egc_analysis2010-2011.pdf7〉.
[71] European Commission. Photovoltaic solar energy – development and current research. Luxembourg: Office for Official Publications of the European Union; 2009.
[72] Jim CY. Green-space preservation and allocation for sustainable greening of compact cities. Cities 2004;21(4):311–20.